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Reconnaissance geology of the Jabal Saq Quadrangle, sheet 26/43C, Kingdom of Saudi Arabia

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

1/ U.S. Geological Survey, Menlo Park, CA 94025

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ABSTRACT

The Jabal Saq quadrangle is located in the northeastern part of the Arabian Shield at the northern end of the Najd region between lat 26°00' and 26°30' N. and long 43°00' and 43°30' E. The northeastern two-thirds of the quadrangle is underlain by Paleozoic sedimentary rocks, the southwestern one-third by Proterozoic metamorphic and igneous rocks. The oldest rocks in the quadrangle are weakly metamorphosed immature sandstones that may correlate with the Murdama group. They have been intruded by several large plutons ranging in composition from mafic granodiorite to syenogranite. A densely developed fracture cleavage cuts the metamorphic rocks; otherwise, no structural features were recorded.

The quadrangle has low mineral potential; no ancient mines were identified. The Dharaymeeah syenogranite forms a large pluton and bears some petrologic resemblance to alkali granites identified elsewhere in the Arabian Shield that have documented potential for containing deposits of lithophile rare metals. Analyses of wadi sediment samples collected in the quadrangle suggest that the syenogranite may also be enriched in some of these elements. The anomalously radioactive Usba monzogranite resembles highly evolved peraluminous granite plutons that elsewhere in the world are associated with deposits of tin and tungsten.

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INTRODUCTION

The Jabal Saq quadrangle, sheet 26/43 C, covers an area of about 2,770 km^2 and is located between lat 26°00' and 26°30' N. and long 43°00' and 43°30' E. at the eastern edge of the Arabian Shield in the Najd province, Kingdom of Saudi Arabia (fig. 1). Approximately 70 percent of the quadrangle is underlain by Paleozoic Saq Sandstone and Tabuk Formation. Crystalline rocks of the Arabian Shield are exposed in the remainder of the quadrangle.

The quadrangle is characterized by low relief; altitudes range from 650 to 880 m. Except for Jabal Saq near the center of the quadrangle, which rises about 40 m above the surrounding plain, local relief does not exceed 10 m. Drainage in the southern part of the quadrangle is to the south into Wadi ar Rimah; drainage in the north is eastward toward Buraydah.

The principal settlements in the quadrangle, Shurayb al Hamrah, Ath Theebiyah, Adh Dharaymeeah, and Al Qarayn, are all located near the southern quadrangle boundary on the principal paved road in the area, the Qassim-Al Madinah highway. Several paved spur roads branch off this highway but most end within a few kilometers at small villages. A longer paved road extends about 20 km northwest from Adh Dharaymeeah, but it also ends at a small village. Unpaved tracks crisscross the remainder of the area and join small settlements.

The geology of the Jabal Saq quadrangle was first mapped as part of the 1:500,000-scale geologic map of the Wadi ar Rimah quadrangle (Bramkamp and others, 1963). Mytton (1970) subsequently studied the mineral deposit potential of the area. No ancient workings or mineral deposits were identified in the quadrangle.

The present report is the result of one week of helicopter-supported geologic mapping conducted during December 1981. The U.S. Geological Survey field camp located at Aban al Asmar (lat 25°48' N., long 43°04' E.) served as a base for the project. The author thanks Ali Mohammed Jabarti, who performed all modal analyses of granitic rocks. Mineral localities referred to in this report are recorded in the Mineral Occurrence Documentation System (MODS) data bank and are identified by a unique five-digit locality number. Inquiries regarding the data bank may be made through the Office of the Technical Advisor, Saudi Arabian Deputy Ministry for Mineral Resources, Jiddah.

The work on which this report is based was performed in accordance with a work agreement between the U.S. Geological Survey (USGS) and the Saudi Arabian Ministry of Petroleum and Mineral Resources.

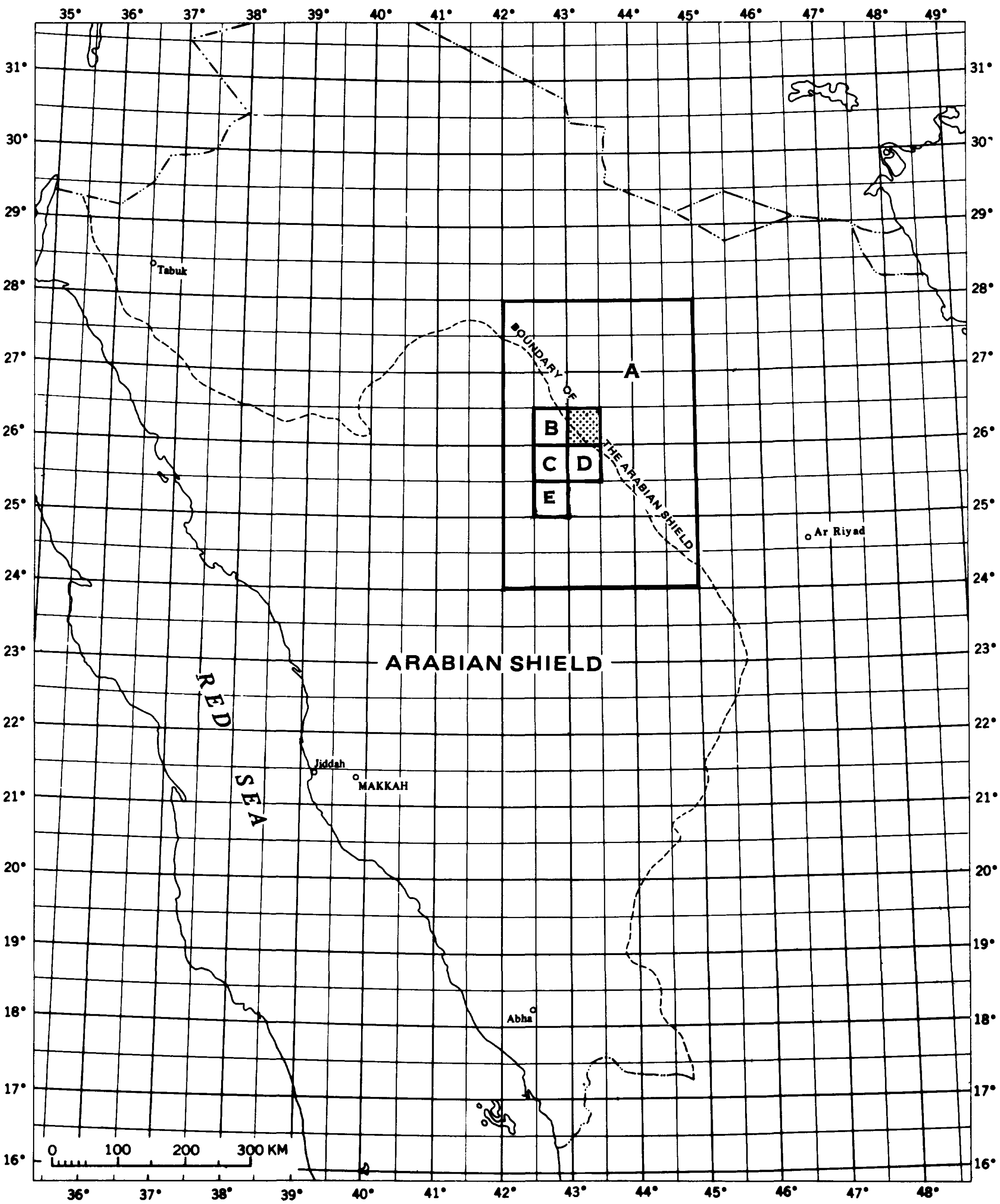

Figure 1.--Index map of western Saudi Arabia showing location of the Jabal Saq quadrangle (shaded) and other quadrangles referred to in this report: A, Wadi ar Rimah (Bramkamp and others, 1963); B, Jabal as Silsilah (du Bray, unpub. data, 1985); C, Al Abanat (Cole, unpublished data); D, An Nabhaniyah quadrangle; E, Al Jurdhawiyah (Cole, in press).

PRECAMBRIAN METAMORPHIC ROCKS

In the Jabal Saq quadrangle, weakly metamorphosed sedimentary rocks crop out in two areas that are separated by 10 km of Phanerozoic sandstone. An extensive area located north-northwest of Ath Theebiyah is underlain by lithic graywacke and is tentatively correlated with a small outcrop of similar rock located west of Jabal al Usba along the western boundary of the quadrangle. This small outcrop is continuous with the Buqaya lithic graywacke that is prominently exposed near the village of Buqaya in the adjoining Jabal as Silsilah quadrangle (du Bray, unpub. data, 1983a).

Buqaya lithic graywacke

The Buqaya lithic graywacke (blg) is a weakly metamorphosed sandstone composed of poorly sorted, subangular clasts of monocrystalline quartz (30 percent), plagioclase (20 percent), and lithic fragments (50 percent). The lithic fragments are of several types, but most were derived from a volcanic terrane. About 80 percent of the fragments are composed of very fine grained siliceous material characterized by volcanic textures, approximately 10 percent appear to be flattened and smeared out pumiceous material, and about 10 percent are fragments of fine-grained, porphyritic mafic volcanic rock. Clasts range in size from silt to medium sand. The argillaceous matrix is the sandstone's cementing agent and is probably composed of finely intergrown chlorite, actinolite, quartz, and feldspar, and locally includes metamorphic biotite. Between 0 and 2 percent opaque oxides, principally detrital, are present. Some opaque grains show well formed crystal outlines and probably grew during metamorphism of the sedimentary rock. The stable mineral assemblage indicates that this unit was metamorphosed at very low greenschist facies. Lithologic characteristics of this unit vary somewhat from the northern to the southern exposures. Grain size and angularity decrease from north to south (up-section), possibly indicative of increasing distance from the detrital source in younger deposits.

The sandstone appears massive in outcrop; however, petrographic study indicates that, at least locally, it is finely laminated. Interbedded siltstone and claystone were identified in places. The unit is intensely fractured and weathers to a surface of low relief. Weathered surfaces are medium to dark greenish to brownish gray; fresh surfaces are medium greenish gray. The graywacke is drained by a finely spaced dendritic wadi system.

The petrologic and structural similarity of the Buqaya lithic graywacke and the graywacke sandstone, exposed in the southern part of the adjacent Jabal as Silsilah quadrangle (du Bray, unpub. data, 1983a), suggests that they are laterally equivalent. This graywacke sandstone is continuous with and lithologically the same as immature metasedimentary rock exposed in the Al Jurdhawiyah quadrangle, which Cole (in press) indicated is continuous with metasedimentary rock exposed at Jabal al Murdamah (Letalenet, 1974). Therefore, the lithic graywacke unit in the Jabal Saq and Jabal as Silsilah quadrangles probably correlates with Murdama group rocks.

The Buqaya lithic graywacke was initially distinguished from the monotonous undifferentiated rocks of the Murdama group that crop out in the southern part of the Jabal as Silsilah quadrangle (du Bray, unpub. data, 1983a) on the basis of appearance on Landsat imagery. The tonal attributes of the Buqaya lithic graywacke make it quite distinct from the undifferentiated Murdama group rocks; however, it is difficult to distinguish the two graywackes on the basis of petrography. The Buqaya lithic graywacke may be finer grained and may contain more pumiceous material and more fine-grained, siliceous volcanic lithic fragments than do the undifferentiated Murdama group rocks. Both units are well cleaved, but cleavage may be more well developed in the Buqaya graywacke. These two graywackes are mappable units of formation rank within the Murdama group.

PRECAMBRIAN INTRUSIVE ROCKS

Plutonic rock crops out in the southwestern one-third of the Jabal Saq quadrangle. Intrusive rock was divided into discrete plutons on the basis of characteristic composition (fig. 2), relations with adjacent rock, dikes, and textural and structural features. Plutonic rock nomenclature follows the guidelines of Streckeisen (1976). Age relations between the plutons were difficult to determine because contacts are poorly, if at all, exposed. Consequently, the indicated age relations, based on dike density and truncations, degree of pluton deformation, and geometric relations between plutons, are tentative.

Quartz monzodiorite

Quartz monzodiorite (qmz) crops out as a small body of low-relief about 10 km south of Jabal al Usba. The quartz monzodiorite is medium grained and hypidiomorphic inequigranular. Biotite and hornblende occur interstitially in a 3:2 ratio and form 35 percent of the rock. Plagioclase, quartz, and potassium feldspar are the felsic constituents (43, 5, and 17 percent, respectively) (fig. 2). Weakly zoned andesine laths are subhedral to euhedral and are dusted with sericite. Quartz and potassium feldspar are subhedral and interstitial. The accessory mineral suite includes sphene, a trace amount of zircon, and about 1 percent opaque oxides.

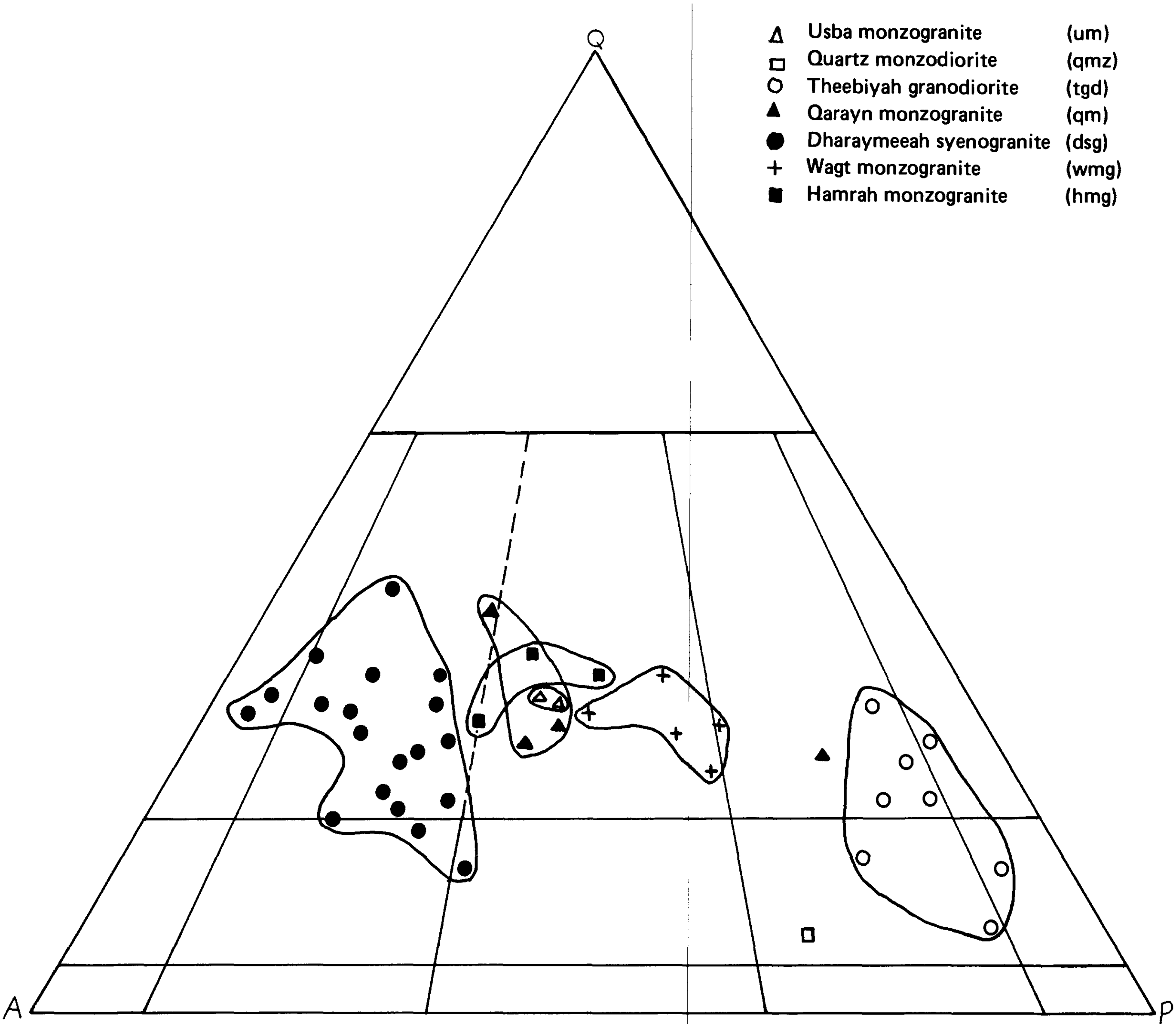

Figure 2.--Ternary quartz-alkali feldspar-plagioclase (Q-A-P) diagram (Streckeisen, 1976) showing the modal composition of intrusive rocks from plutons in the Jabal Saq quadrangle. Each plotted point represents a modal analysis (between 400 and 700 points counted on a stained slab measuring at least 50 cm^2) or a single sample.

Mafic plutonic rock

Mafic plutonic rock (mpr) crops out in the southwestern and southeastern corners of the quadrangle. In the southwestern corner, the unit crops out as several dark-weathering hills, none more than 15 m high. In the southeastern corner of the quadrangle mafic rock crops out over a small area of low relief. The mafic plutonic rock in the southwestern locality is probably a pyroxene metagabbro. It is very fine grained and allotriomorphic granular and is composed of actinolite, plagioclase and epidote; opaque iron oxides constitute about 5 percent of the rock. Rock at the southeastern locality is a fine- to medium-grained, hypidiomorphic inequigranular clinopyroxene gabbro. The color index of this unit is about 30; granular augite and red-brown biotite are equally abundant. Subhedral andesine is moderately zoned. Quartz forms 5 to 10 percent of the bulk composition.

Theebiyah granodiorite

Mafic granodiorite (tgd) crops out as a large, low-relief pluton north of Ath Theebiyah at the western edge of the Paleozoic sedimentary rocks and is cut by a prominent set of dikes. The granodiorite is medium grained and hypidiomorphic inequigranular. The average color index of the granodiorite is 28, and it contains abundant mafic inclusions. Anhedral hornblende and biotite occur interstitially in a 3:2 ratio. Plagioclase, quartz, and potassium feldspar are the felsic constituents (50, 15, and 7 percent, respectively) (fig. 2). Strongly zoned laths of plagioclase are locally dusted with sericite. Potassium feldspar occurs interstitially and poikilitically encloses all other phases. Quartz also occurs interstitially. Zircon and sphene are the principal constituents of the accessory mineral suite in this pluton but apatite, allanite, and opaque oxides are also present. The fact that numerous dikes cut the Theebiyah granodiorite suggests that it predates the other plutons in the quadrangle. A radiometric age determination indicates that the Theebiyah granodiorite crystallized about 614 Ma (C. E. Hedge, written commun., 1982).

Dharaymeeah syenogranite

The Dharaymeeah syenogranite (dsg) underlies much of the southwestern corner of the Jabal Saq quadrangle. This large, undeformed pluton extends westward into the Jabal as Silsilah quadrangle (du Bray, unpub. data, 1983a) and southward into the An Nabhaniyah (25/43 A) and Al Abanat (25/42 B) quadrangles (J. C. Cole, unpublished data). In most places this pluton weathers to a surface of low relief and crops out in flat slabs, but it forms several prominent inselbergs near Shurayb al Hamrah. The Dharaymeeah syenogranite is cut by a few dikes of intermediate composition, but it is not cut by the dikes that cut the Theebiyah granodiorite. The composition of the pluton is equivalent to that of other plutons in the region that are known to have been emplaced about 620 Ma ago (C. E. Hedge, oral commun., 1982). Intrusive geometry suggests that the Dharaymeeah syenogranite was intruded by the Hamrah and Qarayn monzogranites.

The Dharaymeeah syenogranite is characteristically coarse grained, hypidiomorphic inequigranular, and contains no mafic inclusions. The felsic constituents are plagioclase, quartz, and potassium feldspar (15, 27, and 51 percent, respectively) (fig. 2). Strongly perthitic, subhedral potassium feldspar poikilitically encloses quartz and albite. Albite has exsolved as lamellar stringers and patches within potassium feldspar crystals. The color index of the syenogranite is 7. The principal mafic mineral is ferroedenite, the soda-bearing hornblende, that is characterized by pale brownish-green to olive-green pleochroism. Primary, reddish-brown biotite is also characteristic of this pluton. Ferroedenite and biotite occur in a 5:1 ratio and are interstitial. The accessory mineral suite in this pluton is composed of opaque oxides, zircon, allanite, and sphene.

Wagt monzogranite

Potassium feldspar megacryst-bearing monzogranite (wmg) crops out south of the Paleozoic sedimentary rocks at the western boundary of the quadrangle. This recessive-weathering unit also crops out in exposed slabs of pediment. The pluton is named for exposures in Wadi Wagt in the adjacent Jabal as Silsilah quadrangle (du Bray, unpub. data, 1983a).

The potassium feldspar megacrysts are set in a medium- to coarse-grained, hypidiomorphic inequigranular groundmass. The pluton contains less than one mafic inclusion per square meter of outcrop area and has a color index of 10. The similarity of petrographic features and overall geologic setting between the Wagt monzogranite and the Qarayn and Hamrah monzogranites suggests that they were emplaced at about the same time; therefore, it is believed to be younger than the Dharaymeeah syenogranite and the Theebiyah granodiorite.

The felsic constituents are plagioclase, quartz, and potassium feldspar (38, 27, and 25 percent, respectively) (fig. 2). Anhedral microcline occurs principally as perthitic megacrysts as long as 4 cm that poikilitically include quartz and plagioclase. Moderately and complexly zoned plagioclase forms subhedral laths whose cores and zone boundaries are dusted with sericite. Red-brown biotite, occurring interstitially and locally altered to chlorite, is the sole mafic silicate. Trace amounts of zircon, opaque oxides, and secondary epidote are the accessory minerals.

Hamrah monzogranite

The extreme southwestern corner of the quadrangle is underlain by a recessive-weathering monzogranite (hmg) that crops out in flat slabs on the pediment surface. It contains no mafic inclusions and has a color index of 8.

The monzogranite is fine to medium grained, hypidiomorphic granular, and subporphyritic. The felsic constituents are plagioclase, quartz, and potassium feldspar (26, 31, and 35 percent, respectively) (fig. 2). Strongly perthitic phenocrysts of potassium feldspar, less than 1 cm in greatest dimension, poikilitically enclose quartz and plagioclase and are set in an inequigranular matrix of plagioclase, quartz, and biotite. Subhedral laths of moderately zoned plagioclase are weakly sericitized. The distinctive features of this pluton are its relatively fine-grained groundmass, small potassium feldspar phenocrysts, and clotted segregations of biotite. Red-brown biotite containing abundant grains of zircon is locally found in relatively open, subround net-like segregations as much as 1 cm in diameter. Biotite also occurs interstitially. The accessory mineral suite includes trace amounts of zircon, allanite, and opaque oxides.

Qarayn monzogranite

Porphyritic monzogranite (qm), which is somewhat texturally and compositionally inhomogeneous, crops out in the area north and east of Al Qarayn and west of the Paleozoic cover rocks. The monzogranite weathers recessively and is found exposed only in flat slabs of the pediment surface. The mapped outcrop pattern of the pluton is based on its tonal characteristics on Landsat imagery and on stained-slab modes. This pluton petrographically resembles the Hamrah monzogranite, and geologic mapping in the An Nabhaniyah quadrangle to the south may prove that they are contiguous. The pluton contains no mafic inclusions and has a color index of 8. The felsic constituents are plagioclase, quartz, and potassium feldspar (32, 29, and 31 percent, respectively) (fig. 2).

The rock has a rapidly crystallized or quenched appearance. The groundmass is fine to medium grained, allotriomorphic granular, and encloses subhedral phenocrysts of potassium feldspar that are weakly perthitic and that poikilitically enclose quartz and plagioclase. Strongly sericitized plagioclase is weakly zoned and occurs in subhedral laths. Red-brown biotite, locally altered to chlorite, is the sole mafic silicate in the rock and locally contains numerous, small zircon crystals. Sphene is the principal accessory mineral, although trace amounts of zircon, muscovite, and opaque oxides were identified.

Usba monzogranite

A pluton composed of undeformed, fine- to medium-grained, allotriomorphic inequigranular monzogranite (um) is exposed as a low blocky hill in a window through the Paleozoic sedimentary rocks at Jabal al Usba. This fine- to medium-grained intrusive rock, like the muscovite-bearing Fawwarah monzogranite exposed in the adjacent Jabal as Silsilah quadrangle (du Bray, unpub. data, 1983a) is more than twice as radioactive as the rocks exposed elsewhere in Jabal Saq quadrangle. This pluton is similar in composition to other plutons in the region that are known to be about 570 Ma old (C. E. Hedge, oral commun. 1982). If this correlation is correct, the Usba monzogranite pluton is the youngest intrusion in the quadrangle. The monzogranite contains 7 percent colorless to olive-green or pale-tan pleochroic white mica but no mafic silicates or mafic inclusions. The mica includes abundant, prismatic grains of zircon. Felsic constituents are plagioclase, quartz, and microcline (28, 30, and 35 percent, respectively) (fig. 2). Anhedral, nonperthitic microcline occurs interstitially. Subhedral unzoned albite forms laths as long as 1.5 mm, and quartz is subhedral. The accessory mineral suite includes fluorite, zircon, and trace amounts of opaque oxides.

Quartz plugs

Two massive quartz plugs (q) were identified in the quadrangle. One is hosted by the Wagt monzogranite and crops out 1 km west of the quartz monzodiorite. The other is hosted by the Qarayn monzogranite and occurs near the center of that body. Both plugs are composed of massive milky-white quartz and do not appear to be mineralized. They crop out as low mounds that are covered by the rubble of their own mechanical weathering. These quartz plugs are probably related to final aqueous-phase evolution in the two host plutons.

Dikes

In the Jabal Saq quadrangle only the Theebiyah granodiorite is cut by many dikes (d). Dikes in the metamorphic rocks are rare, probably because these rocks were mechanically competent during dike emplacement. The remaining plutons are cut by cogenetic aplite and pegmatite dikes; other dikes are not numerous.

Dikes of the principal set, which penetrate the Theebiyah granodiorite, are approximately east-trending. They are andesitic or basaltic and are composed of plagioclase and hornblende. Primary hornblende phenocrysts and much of the amphibole in the fine-grained groundmass have been replaced by chlorite. Vesicles have been filled by secondary calcite, quartz, and chlorite. Anhedral biotite forms about 5 percent of the dike rock and opaque oxides compose about 10 percent. Apatite is the principal accessory mineral.

Another dike set, comprising only a few dikes having trends that range from northwest to east-northeast, cuts the other plutons of the quadrangle and is probably younger than the principal dike set. These very fine grained, dacitic dikes are equigranular and are composed of plagioclase, quartz, and hornblende.

PALEOZOIC ROCKS

The flat-lying Saq Sandstone is quartz arenite (Williams and others, 1954) that unconformably overlies Precambrian rock and crops out in all but the west-central, southwestern, and extreme northeastern corners of the quadrangle; a complete discussion of the Saq Sandstone is given by Powers and others (1966). Bramkamp and others (1963) constructed a cross section of the Paleozoic sedimentary rocks and suggested that the Sandstone is approximately 600 m thick near its contact with the Tabuk Formation, which crops out in the extreme northeastern corner of the quadrangle.

The contact between the Saq Sandstone and crystalline rocks of the Arabian Shield trends northwest across the quadrangle, and local relief on the erosional surface appears to be small, probably not greater than 10 m. The contact is covered by a thin veneer of sand and gravel so that its precise location is uncertain; even where located, it is not well exposed. Where observed, outcrops of the contact do not suggest either the presence of a paleosol or any other sort of ancient regolith between the crystalline rocks and unconformable sedimentary rocks. The Sandstone weathers to a low-relief surface; only at Jabal Saq in the center of the quadrangle, and to a much lesser extent at the west-central edge of the quadrangle, does this unit form topographic highs. The Sandstone is better indurated at both of these locations.

Saq Sandstone

The Saq Sandstone (OЄs) is a buff to gray and white, moderately well sorted sandstone composed of medium to coarse, subangular to subrounded grains of monocrystalline quartz that show various degrees of strain. The carbonate cement is locally replaced by ferruginous material that case hardens the sandstone and gives it a reddish-brown color. Polycrystalline quartz grains are a trace component. The sandstone is relatively well compacted and is grain-supported. Porosity ranges from 20 to 30 percent.

Within the mapped area, the Saq Sandstone is homogeneous. Neither silty, conglomeratic, shaley, nor pebbly beds were observed, although such beds are reported to occur elsewhere in the formation (Bramkamp and others, 1963). The Sandstone is massively bedded although small-scale crossbedding is locally present. Powers and others (1966) provide a good summary of the efforts made to establish the age of the Saq Sandstone. They indicate that it records Early Cambrian through Early Ordovician sedimentation.

Tabuk Formation

The Tabuk Formation (DSOt) overlies the Saq Sandstone at the extreme northeastern corner of the quadrangle, but this area was not visited during mapping. Bramkamp and others (1963) report that the Tabuk is a red to pink and light-gray, brown, and buff sandstone that is locally micaceous and silty. Three sandstone units and three shale units, found at the base of the Formation and between the sandstone units, form a 700-m-thick section near Burayda; however, only 35 m at the base of the section are exposed in the quadrangle. Micaceous, silty, and sandy shale members are blue gray, olive brown, olive green, purple, and varicolored. A discussion of the Tabuk Formation, including its heavy-mineral suite, is presented by Powers and others (1966). The sandstones are locally crossbedded and contain abundant vertical tubular casts, probably worm burrowings, Scolithus. The lowermost part of the Tabuk contains graptolites, and pelecypods, gastropods, and brachiopods are locally present 500 m above the base. From this fossil evidence, Powers and others (1966) suggest that the Tabuk Formation represents deposition from Early Ordovician through Early Devonian time.

QUATERNARY DEPOSITS

The Quaternary deposits of the Jabal Saq quadrangle include alluvium (Qal) in active wadi channels and gravel in pediment deposits. Drainage in the quadrangle is principally to the south via a dendritic net that feeds into Wadi ar Rimah. The deposits in these wadi systems are principally composed of well rounded sand but include silt, pebbles, and cobbles. Coarse gravel deposits are locally present. Eolian material is a minor constituent of wadi channel deposits. The crystalline rocks of the Arabian Shield form a pediment surface in the Jabal Saq quadrangle, which is covered by a thin veneer of lag gravel intermixed with windblown sand and silt.

STRUCTURE

The rocks exposed in the Jabal Saq quadrangle contain relatively little structural information especially concerning bedding orientation. The intrusive rocks are massive and do not display flow foliation, nor do petrographic studies indicate postcrystallization deformation. The metasedimentary rocks are of such uniform appearance that the trend of bedding is difficult to discern in the field; the trend of bedding plotted on plate 1 was best determined from aerial photography. A set of very closely spaced fracture cleavage planes transects the metasedimentary rocks and further obscures bedding traces. Outcrops are shattered, and it is difficult to collect a specimen that exceeds half-fist size.

The structural characteristics of the Buqaya lithic graywacke are very similar to those of the Maraghan lithic graywacke, which is exposed throughout the southern half of the adjacent Jabal as Silsilah quadrangle (du Bray, unpub. data, 1983a). The Buqaya graywacke dips subvertically and strikes in a northwesterly to northerly direction. It has been deformed into broad, generally open, but locally isoclinal and steeply plunging folds. Another, or possibly the same, compressional event produced the west-northwest-trending fracture cleavage, which is also well developed in the metasedimentary rocks in the adjacent areas. The relatively consistent strike of the regional fractures suggests a second deformational event that postdated the event that produced the folds.

A prominent lineament, apparent on the aeromagnetic map of the Jabal Saq and the Jabal as Silsilah quadrangles, strikes approximately N. 80° W. between a point about 7 km north of Al Qarayn to a point about 11 km north of Shurayb al Hamrah. The close spacing of the aeromagnetic contours indicates that the anomaly source is not a deep crustal feature but a rather shallow one and may indicate iron oxide deposition in a major fracture or fault zone. The structural implications of this feature are currently unknown. It does not coincide with any discontinuity on the ground, it does not correlate with geologic boundaries, and it has no relation to the spacing of fracture cleavage in the metasedimentary rocks.

Pinkish-orange weathering siliceous carbonate material is found in a restricted area between metagabbro and the Buqaya lithic graywacke in the southwestern part of the quadrangle. Outcrops of the carbonate are few and very recessively weathering, but this rock is similar to altered carbonate rock found in and along the Raha fault zone to the northwest in the Jabal as Silsilah quadrangle (du Bray, unpub. data, 1983a). The occurrence of carbonate rock and metagabbro in the area immediately south of the Buqaya lithic graywacke suggests that the trace of the Raha fault zone may pass through this area. The trace of the fault zone, between its easternmost position in the Jabal as Silsilah quadrangle and this site in the southwestern corner of the Jabal Saq quadrangle, has been obliterated by intervening plutons. As an even more tentative hypothesis, it is suggested that the Raha fault zone trends southeast across the Jabal Saq quadrangle and may be coincident with metagabbro that crops out in the southeastern corner of the quadrangle.

GEOCHEMISTRY AND PETROGENESIS

Representative major element analyses of samples from three of the plutons are presented principally for documentary purposes in table 1. The data were plotted on standard normative quartz-albite-orthoclase (Q-Ab-Or) (fig. 3) and ACF (molar ratios, A = Al_2O_3-Na_2O-K_2O; C = CaO; F = FeO+MgO) (fig. 4) ternary diagrams to facilitate comparison with other plutonic rocks. One sample analysis for each of the three plutons cannot provide statistically valid estimates of their mean compositions, but tentative generalizations regarding their chemistry can be made. Results of additional analyses of samples of these plutons, collected in the Jabal as Silsilah quadrangle (du Bray, unpub. data, 1983a) corroborate the ideas presented below.

The composition of the Theebiyah granodiorite plots well away from reasonably appropriate minima (fig. 3) and contains large amounts of components not represented by this plot. The phase relations represented on the Q-Ab-Or diagram are therefore inapplicable to crystallization of the Theebiyah granodiorite. The magma represented by the Theebiyah granodiorite probably evolved by advanced partial melting of a relatively unevolved protolith and (or) represents a mafic melt that experienced very little fractionation of early-crystallized phases during its crystallization. In contrast, the position of the sample of Hamrah monzogranite (fig. 3) indicates that this is a highly evolved magma that probably crystallized at a relatively shallow level. The textural characteristics of rock in this pluton also suggest shallow emplacement. The magma represented by this pluton resulted either from minimum melting or from substantial evolution of a less evolved magma via fractional crystallization. The composition of the sample of Dharaymeeah syenogranite suggests that this pluton had a genesis and evolutionary path intermediate to those for the Theebiyah granodiorite and the Hamrah monzogranite.

Data for the same three samples were plotted on an ACF ternary diagram to compare them to I- and S-type granites (fig. 4). The dividing line shown on figure 4 is one proposed by White and Chappell (1977) to separate I-type granites (those that may host porphyry-type mineral deposits of copper

Table 1.--Major element analyses and CIPW norms (calculated after analyses normalized to 100 percent, anhydrous) for selected intrusive rocks in the Jabal Saq quadrangle

[Rapid rock analyses performed in the DGMR-USGS chemical laboratory, Jiddah, using techniques described by Shapiro and Brannock (1962). All values in weight percent]

Pluton	Hamrah monzogranite	Dharaymeeah syenogranite	Theebiyah granodiorite
Sample number	181419	181462	181457
latitude (north)	26°00'13"	26°03'49"	26°08'56"
longitude (east)	43°00'33"	43°13'02"	43°09'04"
	Chemical analyses		
SiO_2	73.4	71.1	62.9
Al_2O_3	13.0	14.2	16.8
Fe_2O_3	0.72	1.09	0.35
FeO	1.60	1.58	4.00
MgO	.37	.10	2.15
CaO	1.03	1.25	4.85
Na_2O	3.70	4.00	4.80
K_2O	4.70	5.40	2.30
H_2O	.45	.76	.71
TiO_2	.72	.22	.57
P_2O_5	.29	.10	.24
MnO	.05	.13	.09
Total	100.0	99.9	99.8
	CIPW norms		
Q	31.5	24.1	11.6
C	.7	0	0
or	27.9	32.2	13.7
ab	31.4	34.1	41.0
an	3.2	4.9	17.7
wo	0	.3	2.1
en	.9	.3	5.4
fs	1.2	1.9	6.3
mt	1.0	1.6	.5
hm	0	0	0
il	1.4	.4	1.1
ru	0	0	0
ap	.6	.2	.6

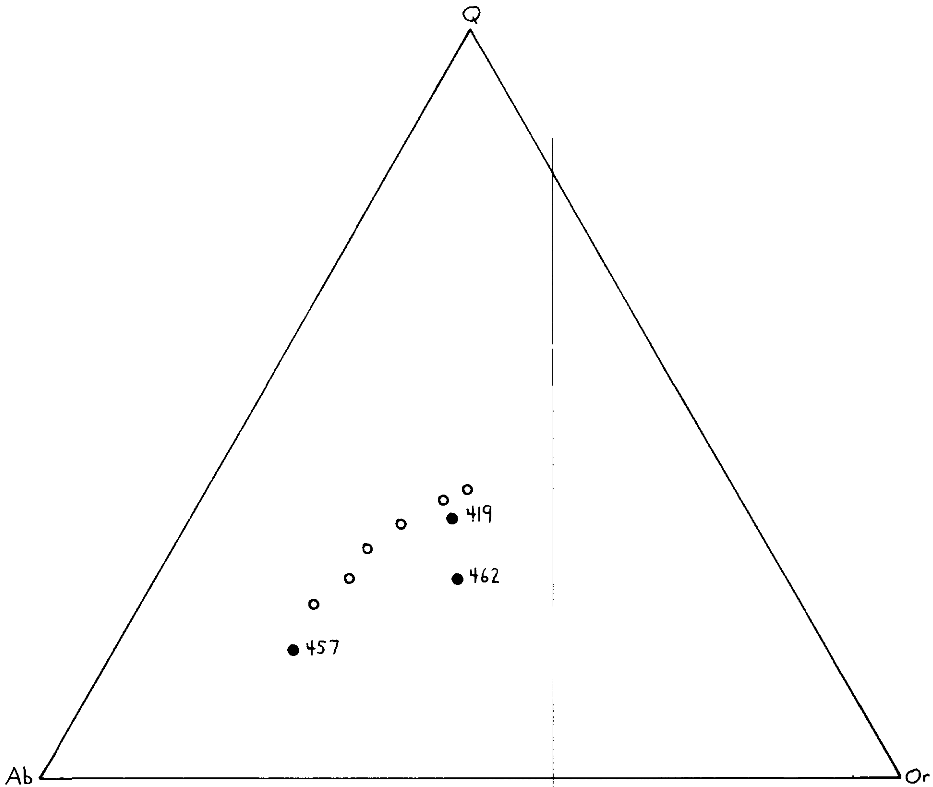

Figure 3.--Ternary quartz-albite-orthoclase (Q-Ab-Or) diagram showing the chemical composition of rocks from selected plutons in the Jabal Saq quadrangle. Numbers next to data points are prefixed by 181 to obtain sample numbers, which correspond to table 1. Open circles, from top right to bottom left, represent the minimum melting compositions in the experimental system SiO_2-$KAlSi_3O_8$-$NaAlSi_3O_8$-H_2O for P_{H_2O} = P_{Total} = 50, 100, 200, 400, 500, and 1000 megapascal (mPa) (0.5, 1, 2, 4, 5, and 10 kbar) (Winkler and others, 1975).

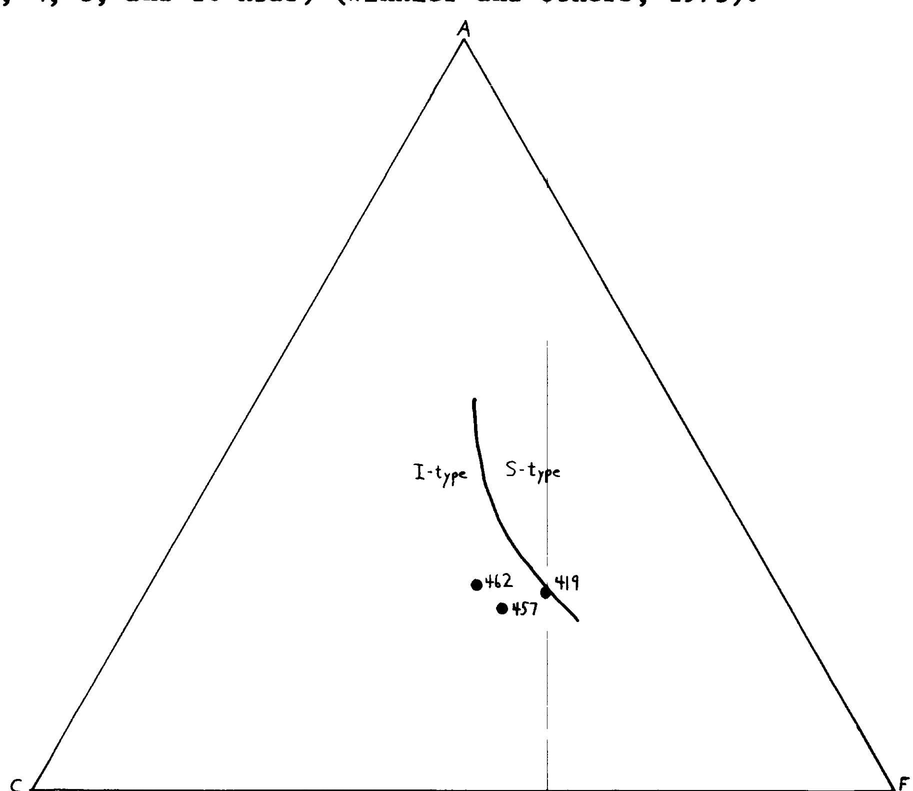

Figure 4.--Ternary ACF diagram showing the chemical composition of rocks from selected plutons in the Jabal Saq quadrangle. Numbers next to data points are prefixed by 181 to obtain sample number. The curve represents the boundary suggested by White and Chappell (1977) between I-and S-type granite compositions.

and molybdenum) and S-type granites (those that may be associated with tin deposits). The Hamrah monzogranite has a composition transitional between that characteristic of I- and S-type granites and may have some potential for associated tin deposits. The fact that the other two samples plot well away from the S-type field suggests that the rocks of the plutons have little potential for associated tin deposits. Two samples of the Dharaymeeah syenogranite, collected in the adjacent Jabal as Silsilah quadrangle (du Bray, unpubl. data, 1983a) plot near the line that separates the I-type field from the S-type field, however, and suggest that this pluton too may have some potential for associated deposits of tin.

The Dharaymeeah syenogranite has chemical and petrographic similarities to the peralkaline granite clan. Peralkaline granite is characterized by high contents of SiO_2 and alkali elements, by a low content of Al_2O_3, and by enrichment of incompatible lithophile elements (Drysdall and Drysdall, 1982). The feldspar in these rocks is strongly exsolved perthite, and the rocks contain soda pyriboles. The syenogranite is characterized by these features and contains ferroedenite. Ferroedenite is on the chemical continuum between calcic hornblende, characteristic of metaluminous granite, and soda amphiboles, characteristic of peralkaline granite (D. B. Stoeser, oral commun., 1983). The composition of the Dharaymeeah syenogranite is probably on the continuum between metaluminous and peralkaline granites.

ECONOMIC GEOLOGY

No ancient mine sites were identified in the Jabal Saq quadrangle; however, a geochemical survey indicates that the area has some mineral potential. Pan concentrates were prepared from wadi sediment collected at 100 locations in the quadrangle as part of the geochemical survey conducted by the USGS in the northeastern Arabian Shield (R. Samater, unpublished data). Many samples collected in the wadis that drain the Dharaymeeah syenogranite pluton contain conspicuously anomalous concentrations of tin, and several contain anomalous concentrations of tungsten (R. Samater, unpublished data). This syenogranite pluton has an affinity for the peralkaline granite clan, and the peralkaline granites in Saudi Arabia are associated with low-grade deposits of zirconium, niobium, tantalum, tin, zinc, and rare-earth elements. The Dharaymeeah syenogranite may have similar mineral potential and therefore warrants further study.

The petrographic character of the Usba monzogranite resembles that of peraluminous granites located elsewhere in the Arabian Shield that have documented potential for deposits of tin and tungsten (du Bray, in press). These peraluminous granites are characterized by their highly evolved chemistry, including high content of SiO_2, low contents of CaO, TiO_2, MgO, and total iron, and extreme enrichment of the incompatible lithophile elements. Elsewhere in the world, this rock type is associated with deposits of tin, tungsten, and other rare metals. The Usba monzogranite may have similar potential and warrants additional study.

Only one Mineral Occurrence Documentation System locality (MODS 02206) is listed for the Jabal Saq quadrangle. This MODS entry corresponds to an airborne radiometric anomaly coincident with part of the Tabuk Formation sandstone that contains anomalous concentrations of zirconium, thorium, vanadium, uranium, cerium, lanthanum, neodymium, and other rare-earth elements. Matzko and others (1978) indicate that unusual concentrations of detrital radioactive-element-bearing heavy minerals, including zircon, sphene, allanite, monazite, xenotime, and huttonite, are found in this part of the Tabuk sandstone. Most of the radioactivity is due to thorium decay, and the heavy-mineral concentrations contain very little uranium. Because the uranium concentrations are so low and the radioactive zone so thin, this occurrence is not of economic interest.

Friable metagabbro is being quarried at a location midway between Shurayb al Hamrah and Ath Theebiyah (plate 1) and is probably being used for local road aggregate. The area underlain by the metagabbro is relatively small, but is probably large enough to meet local needs.

DATA STORAGE

No updated information was added to the Mineral Occurrence Documentation System data bank.

Documents relating to this project have been stored in data file USGS-DF-03-5.

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